Evaluating Photovoltaic Applications

A Guide for Utilities

This guide was prepared by Sandia National Laboratories to help decision makers in electric utilities identify and evaluate possible applications for photovoltaics.

The guide contains instructions on how to estimate the size and cost of a photovoltaic system, information about photovoltaic systems suitable for utility applications, and general facts about photovoltaic systems.

Sandia National Laboratories

U.S. Department of Energy

FACTS ABOUT PHOTOVOLTAICS

Photovoltaics

The word "photovoltaics" comes form "photo" for light and "voltaic" for voltage. It means electricity from sunlight.

Solar Cell

A typical solar cell is a thin rectangular or circular wafer, usually made from silicon and other common elements. When solar cells are exposed to light, electrons inside them are freed and flow through a connecting wire to power motors, lights, or other electrical equipment.

Module

Cells are connected by wires and mounted within a frame to form a photovoltaic module. The more cells in a module, the more power that can be produced.

Array

Modules can be connected by wires to form an array; the more modules, the more electricity that will be available to power electrical equipment and appliances. The desired power, voltage, and current can be obtained by connecting individual modules in combinations of series and parallel to serve a specific load.

AC, DC

The electricity coming from the array or modules is dc. It can be used directly to operate loads using dc, it can be used to charge batteries, or it can be fed through an inverter to convert the dc to regular 60-cycle ac power.

Stand-Alone

Stand-alone photovoltaic systems are those that are not connected to the utility grid and are practical where small amounts of electricity are needed or where the grid is unavailable.

Grid-Intertied

Grid-intertied systems are connected to the utility grid. Electricity generated by the array that is not used by a specific load is fed back into the utility system.

Introduction

For many applications on utility systems today, photovoltaics provides a cost-effective energy source for serving low power loads. In certain applications, photovoltaics can be utilized as a cost-effective alternative to distribution line extensions or step-down transformers.

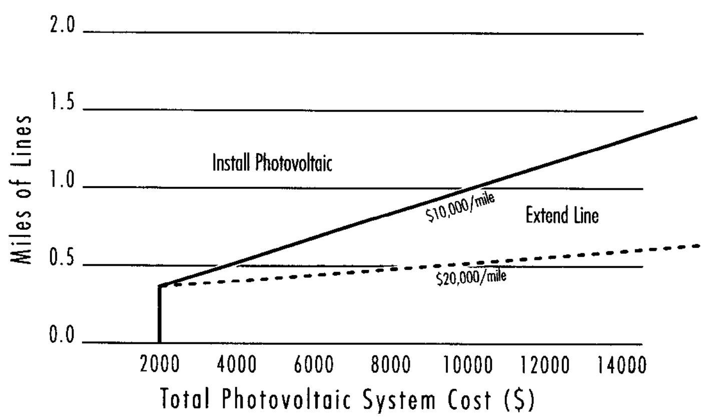
This guide was written primarily for utility personnel to use in determining whether photovoltaics compares favorably with the cost of extending the utility line. The applications listed at the end of this pamphlet are limited to those that have immediate payback—systems for which photovoltaics is a less expensive option than conventional service would be.

Scores of applications exist today for photovoltaic systems within utility companies; this publication suggests only a few of the many possibilities. Sandia National Laboratories Photovoltaic Design Assistance Center is a resource for utilities and agencies, providing contact among potential users of photovoltaic systems, suppliers of systems and components, and qualified engineers who evaluate needs and available equipment.

Contact persons at Sandia's Design Assistance Center are Roger Hill, 505-844-6111 or John Stevens, 505-844-7717.

Service for isolated, low-energy, or low-revenue loads is costly for both the utility and its customers. Although line-extension policies provide a method for the utility and the customer to share the expense of service, revenue from low-power-use loads may not cover annual operation and maintenance costs for the installation. Photovoltaic systems can provide service to low-revenue loads that would not normally be economically feasible to serve even with generous line extension policies.

Illustrated is the break-even line of the cost to extend the utility grid versus purchasing a photovoltaic system based on the cost for a single-phase distribution line of $10,000 a mile. A higher cost for line extension will increase the potential for cost-effective photovoltaic systems.



Generally, a photovoltaic system will be cost-effective if the peak load is 1 kW or less. If the annual energy consumption is 500 to 1000 kWh, compare the cost for a photovoltaic system with cost for conventional service. If the annual consumption is less than 150 kWh a year, a photovoltaic system is recommended.

When estimating the cost of a photovoltaic system, consider both available sunlight and the seasonal demands of the load. For example, a tower beacon light operates longer in the winter, when there is less sunlight, resulting in a prolonged operating period with fewer hours of sun available for charging batteries. For some loads, the heaviest load may not occur on a day when the available sunlight is the lowest. When evaluating loading requirements and energy availability for photovoltaic systems, consider both worst case loading and worst case solar resource conditions (see page 6). Recognize that the two do not necessarily occur together.

WORKSHEET

Estimating the Cost of Photovoltaic Systems

Determine the load, available sunlight, array size, batteries:

1. Determine the energy the load requires in Wh per day:
   Multiply the number of watts the load will consume by the hours per day the load will operate.
   Multiply this figure by a fudge factor of 1.5.

   TOTAL WH PER DAY REQUIRED . . . . ________

2. Determine the hours of available sunlight at the site (see page 6):
   Information is also available from Sandia's Design Assistance Center or the National Climatic Data Center.

   TOTAL AVAILABLE SUNLIGHT . . . . ________

3. Determine the size of the array that will be needed:
   Divide the energy needed (1) by the number of available sun hours (2); consider worst case conditions. Divide .. the results by module size, round up (for estimating purposes, an average module size is 50 watts, 12 volts dc).

   TOTAL ARRAY SIZE REQUIRED . . . . ________

4. Determine the size of the battery bank (if one is required):
   Multiply the load (1) by 5 (result is watthours). Then divide the battery voltage (for example, 12 volts) to get amphour rating of battery bank.

   TOTAL BATTERY BANK . . . . ________

Calculate the cost of the photovoltaic system needed for this application:

1. Multiply the size of the array (3) required by $6 per watt:
   a 50-watt photovoltaic panel costs $300 (based on 1993 prices). . . . . ________
2. Multiply the size of the battery bank by $1 per amp hour (based on 1993 prices):
   $1 per amp hour is used for estimating; (flooded lead acid batteries). . . . . ________
   Subtotal: . . . . ________
3. Multiply subtotal by 20% for balance of system costs (wire, fuses, switches, etc.): . . . . ________

TOTAL COST FOR PHOTOVOLTAIC SYSTEM . . . . ________

Calculate the cost for conventional line extension:

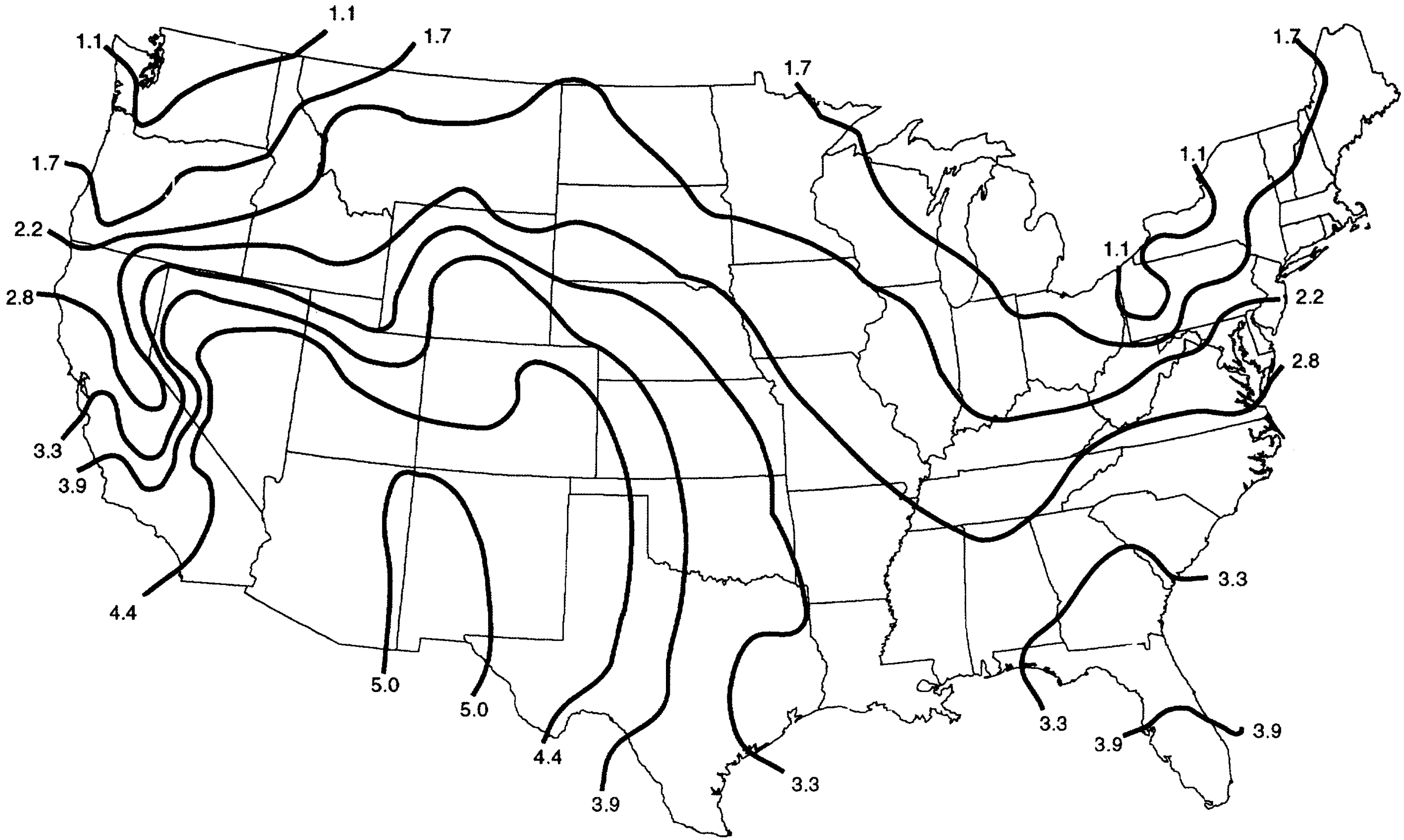
1. Multiply the distance from the distribution line to the load by the cost per mile for line extension (normal range is $10,000 to $40,000 a mile); deduct any normal line extension credits; include the cost of a stepdown transformer for transmission line:

   TOTAL FOR LINE. . . . . ________

2. Add costs for permits, pavement cuts, labor, annual maintenance, safety, etc:

   TOTAL EXTRA COSTS . . . . ________

TOTAL COST FOR CONVENTIONAL LINE EXTENSION . . . . ________



Values on the map are average insolation in units of $kWh/m^2/day$ (sun-hours) for a surface at latitude tilt for December. These values typically represent the "worst case" solar resource month. Seek other data if December does not represent the worst design case.

RECOMMENDED PRACTICES

Photovoltaic systems are easy to design, install, and maintain. Experienced designers and installers of photovoltaic systems provide the following recommendations to help ensure a system will operate reliably for two decades.

SIMPLICITY Keep the system simple. Complexity lowers its reliability and increases the need for technical support.

AVAILABILITY Understand what "availability" really means; achieving 99% availability with a renewable energy system is expensive.

LOAD ESTIMATES Be thorough but realistic when estimating the load. Many so-called system failures are the result of underestimating loads. The only negative aspect in overestimating is an increase in the cost of the system.

SUNLIGHT Errors in estimating the solar resource can cause disappointment in the photovoltaic system's performance.

HARDWARE Know the available hardware and its cost. Tradeoffs are inevitable in building a system.

SITE Know the site where the system will be installed before designing the system so the placement of components, wire runs, shading, and peculiarities of the terrain can be determined.

INSTALLATION Install the system carefully. Make each connection as if it had to last 30 years–it does.

MAINTENANCE Plan periodic maintenance. Photovoltaic systems have an enviable record for unattended operation, but no system works forever without some care.

ADVANTAGES OF PHOTOVOLTAIC SYSTEMS

THE SUN The solar resource, the only energy required, occurs everywhere on the planet.

NO FUEL Photovoltaic systems require no fuel, thus they have no combustion by-products. In addition, there are no fuel costs.

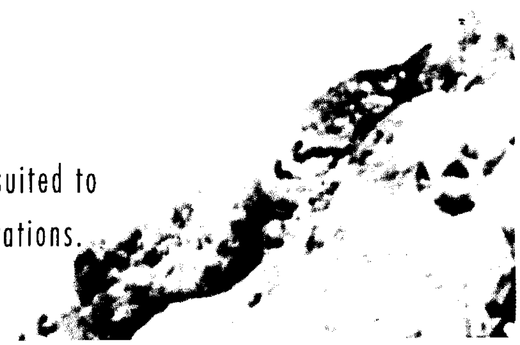
LOW O&M Photovoltaic systems use solid-state technology and no moving parts are required. Their operation requires little maintenance while providing high reliability.

SIMPLE INSTALLATION Photovoltaic systems are inherently simple. Because of this and their modularity, they are relatively fast and easy to install.

MOBILITY With their variety of sizes and their modular design, photovoltaic arrays can be mounted on trailers or skids to allow ready movement to another location.

SITING Photovoltaic arrays can be installed on or very near the load they are serving; for example, on a roof, on the ground, in a substation .

NON-POLLUTING Because nothing is burned or consumed, photovoltaic systems generate no hazardous waste nor do they emit toxic fumes.



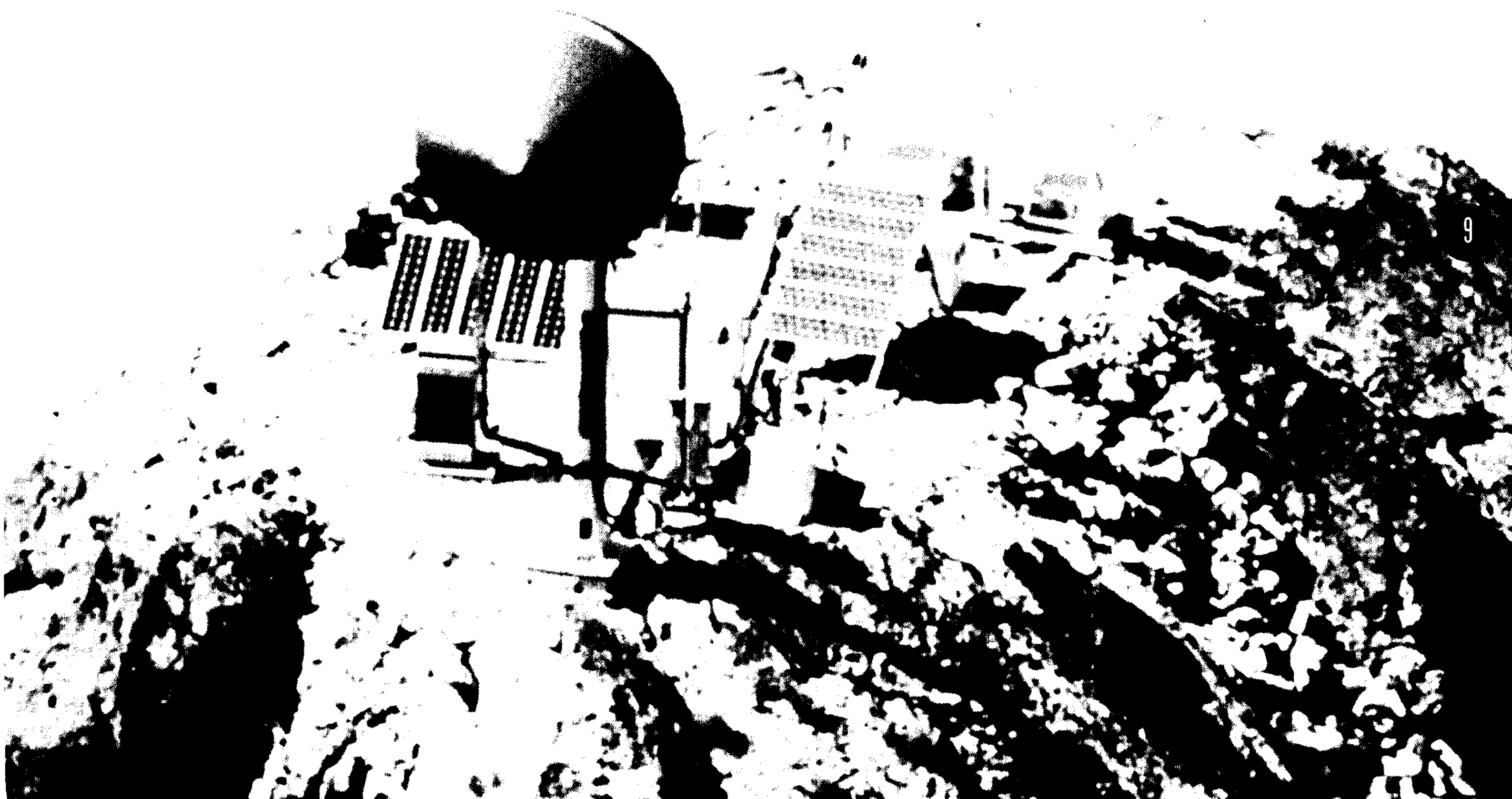
COMMUNICATION: Photovoltaic systems are ideally suited to provide power for mountaintop communication stations.

Examples

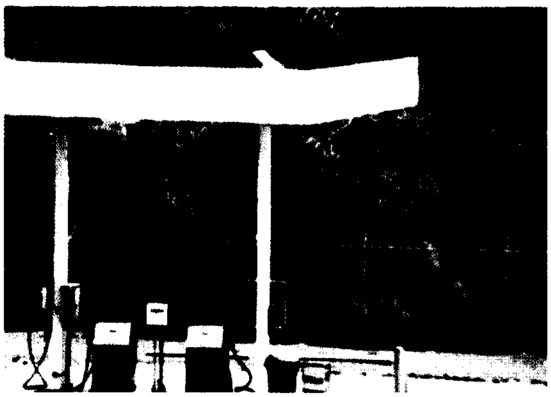
OF COST EFFECTIVE PHOTOVOLTAIC SYSTEMS FOR UTILITY APPLICATIONS

PORTABLE POWER Photovoltaic arrays may be mounted on trailers to be moved where energy is needed.

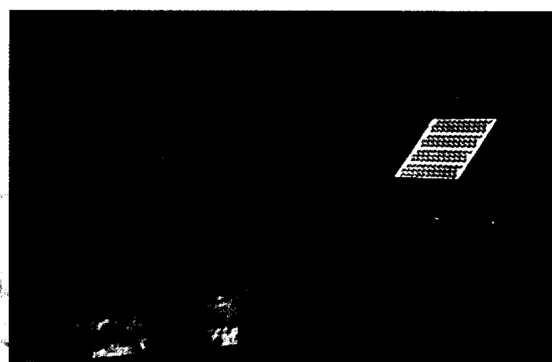
WARNING SIGNALS Photovoltaic systems offer utilities the ability to illuminate tower beacons without expensive transformers or line service.



More Examples



CATHODIC PROTECTION Photovoltaic panels can be retrofitted to existing facilities. Here photovoltaic technology provides cathodic protection for underground fuel storage tanks.



REMOTE BUILDINGS Photovoltaic technology is a cost-effective, environmentally benign energy source for remote homes and summer cabins.

WATER PUMPING Photovoltaic panels can power pumps to supply water for wildlife in preservation areas.

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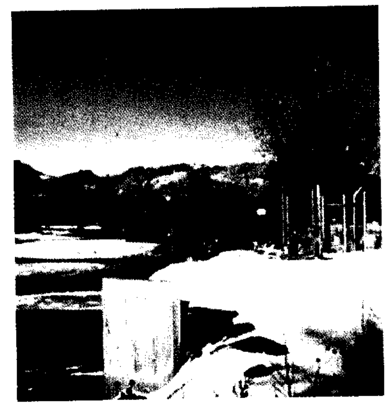
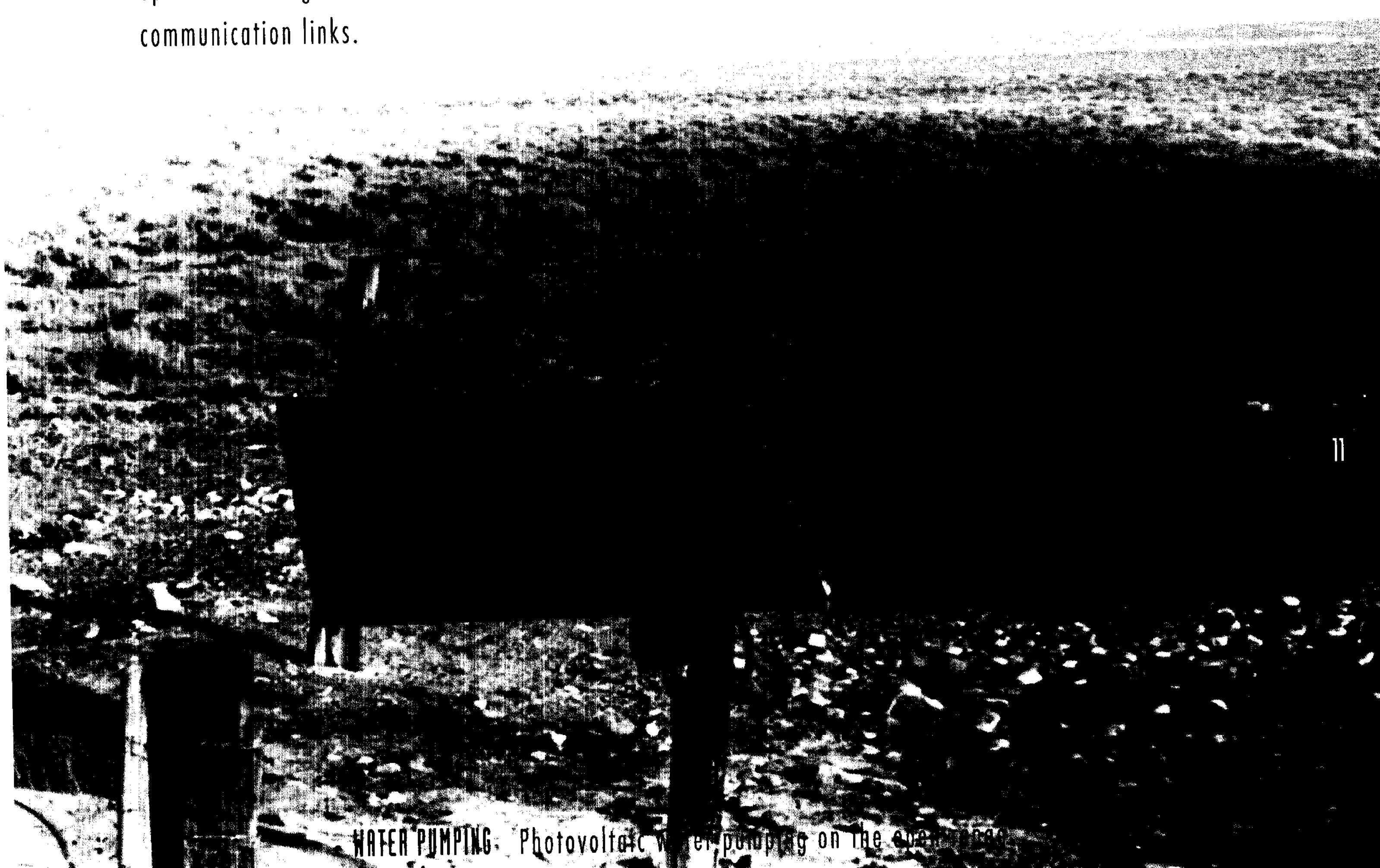
SECTIONALIZING SWITCHES Switches powered by photovoltaics combined with energy storage and motor operators provide utilities with cost-effective remote switch operation through communication links.

WARNING SIGNALS Road signs can be illuminated wherever needed, regardless of the availability of nearby utility service.



MONITORING AND CONTROL Monitors such as those for water levels, flow rates, and weather stations can be reliably powered using photovoltaics.



WATER PUMPING Photovoltaic water pumping on the [illegible]

147

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